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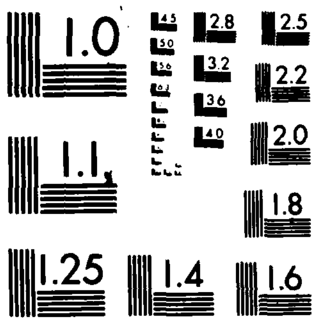
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Abstract : We discuss current problems in storage ring laser development : optics degradation, and the low gain available on unoptimized existing electron sources. We introduce the field with experimental data, and conclude with the most recent results.

To be presented at CLEO '83
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A storage ring free electron laser uses an electron storage ring as the relativistic electron beam source, and an undulator magnet structure to couple the kinetic energy of the electrons into coherent laser light. Work has been underway for three years on the storage ring ACO at Orsay, France to realize a free electron laser (FEL) on a recirculated beam, with the goal of increasing the power and efficiency of the FEL. Considerable progress has been made towards the initial goal of achieving oscillation and only one problem --mirror degradation-- now stands in the way of success.

Two undulators hare been studied at Orsay, the first of which had a serious magnetic field distortion problem. This problem has made possible the experimental (and theoretical) identification of the effects of electron trajectory errors on the performance of FEL's [1]. The second Orsay undulator was designed so as to eliminate these problems, and has shown detailed equeement with the theory in its operation [2].

A modification of the undulator called the optical klystron (first operated at Novosilinsk [3]) has recently been constructed and tested at Orsay [2]. We have measured the gain with both undulators [1, 2], and more recently with the optical klystron modification. The results provide experimental confirmation of the Madey theorem [4]. The maximum peak gain per round trip in the optical cavity is 7.2×10^{-4} with the optical klystron in the Orsay system. This is an increase of a factor of five over the maximum measured undulator gain, as predicted by the theory.

We have obtained and measured several sets of multilayer SiO_2 and TiO_2 mirrors with total losses per round trip of less than 3×10^{-4} in air. These mnirrors are inserted directly into the 10^{-10} Torr vacuum of the storage ring to eliminate window losses. Although the initial losses of the mirror pairs is sufficiently low to permit oscillation, their reflectivity degrades [2] both during insertion into the vacuum and as a result of exposure to the high flux of hard UV radiation emitted as harmonics of the undulator frequency.

We plan to test a few other mirror materials and configurations at Orsay, but a systematic attack on the mirror degradation problem is clearly needed.

The gain available on ACO is limited by the current density and straight section length. With the optical klyston in place, maximum use is made of the straight section, and the gain may be increased only by increasing the current density which depends on the magnet lattice and energy. On the other hand a new machine with high current density and a long straight section for the undulator could be expected to operate with a gain on the order of unity.

We also have measured the bunch lengthening effect [5] of the laser interaction on the stored electron beam. At low current, the magnitude and spectrum of the effect is in agreement with the theory which demonstrates that we understand at least one of the fundamental phenomena which will be responsible for saturation once the storage ring laser operates. At high the current, the coupled interactions of the "laser-induced" and the "anomalous" bunch lengthening which we have now observed indicate the need for more theoretical work.

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